

# Modified Fragmentation Function from Quark Recombination

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Data from experiments at the Relativistic Heavy-ion Collider (RHIC) have indeed confirmed the predicted features of jet quenching. However, there also exists considerable evidence for parton recombination in the measured hadron spectra in heavy-ion collisions at RHIC. At intermediate  $p_T = 2 - 4$  GeV/c, the suppression of baryons is significantly smaller than mesons, leading to a baryon to meson ratio larger than 1. This is about a factor of 5 increase over the value in  $p + p$  collisions. On the other hand, the azimuthal anisotropy of the baryon spectra is larger than that of meson spectra.

We present a first attempt [1] to derive the recombination model of jet fragmentation functions from a field theoretical formulation and the constituent quark model of hadron structure. Within the constituent quark model, we consider the parton fragmentation as a two stage process. The initial parton first evolves into a shower of constituent quarks that subsequently will combine with each other to form the final hadrons. Since constituent quarks are non-perturbative objects in QCD just like hadrons, the conversion of hard partons into showers of constituent quarks is not calculable in pQCD. However, we can define constituent quark distributions in a jet as overlapping matrices of the parton field operator and the constituent quark states.

The results of such an analysis, indicates that, if the hadronic wavefunction of a meson  $M$  i.e.,  $\phi_M(q_1, q_2)$  in the constituent quark model is sharply peaked, then we can approximate the meson fragmentation function as a convolution of a double constituent quark distribution function  $F_q^{q_1 q_2}$  and a recombination probability for the coalescence of the two constituent quarks into a meson, (in the prevalent terminology such constituent quarks which appear in the vacuum fragmentation of a jet are called shower particles and the recombination scheme is called “shower-shower” recombination)

$$D_q^M(z_M) \approx C_M R_M(q_1, \bar{q}_2) \otimes F_q^{q_1 \bar{q}_2}, \quad (1)$$

In the above, the recombination probability  $R_M(q_1, \bar{q}_2)$  is nothing other than the square of the meson wavefunction  $|\phi_M(q_1, q_2)|^2$ . Like the dihadron fragmentation functions, the diquark distribution function need to be measured at a given scale and their variation with scale can be predicted by a QCD evolution equation similar to the dihadron fragmentation functions. However, since the hadrons' wavefunctions in the constituent quark model restricts the relative transverse momentum of the constituent quarks within a hadron to a finite value, we have an intrinsic transverse momentum cutoff  $\Lambda$  in the definition of the double constituent quark distributions that are relevant for quark recombination, as a result the evolution of the double constituent quark distribution function that is relevant to the recombination into a hadron lacks the independent

fragmentation piece in the evolution of the regular dihadron fragmentation functions, (See Ref. [1] for details).

Within such a setup, one can describe the fragmentation of a parton jet in medium simply by replacing the vacuum expectation in the  $S$  matrix of the processes or the operator definition of the parton fragmentation functions by their thermal expectation values,  $\langle 0|O|0 \rangle \rightarrow \langle \langle O \rangle \rangle$ ,

$$\langle \langle O \rangle \rangle = \frac{\text{Tr}[e^{-\hat{H}\beta} O]}{\text{Tr} e^{-\hat{H}\beta}}, \quad (2)$$

where,  $\hat{H}$  is the Hamiltonian operator of the system and  $1/\beta = T$  is the temperature. Evaluating the operator corresponding to the fragmentation function as above, one obtains three types of contributions. The first term is the contribution from recombination of two shower quarks from parton fragmentation as shown above. The second term corresponds to a processes in which a quark from the thermal medium combines with another quark from the parton fragmentation (or shower) to form the final meson. These processes are called “shower-thermal” quark recombination and are illustrated in Fig. 1. Finally, the third term corresponds to the formation of the final meson from two thermal quarks in the quark recombination model. This is referred to as “thermal-thermal” quark recombination. However, such contributions of thermal quark recombination are disconnected with parton jet fragmentation and therefore are just a thermal background to jet fragmentation processes in the medium. All these contributions appear naturally from the above formalism. There is no inbuilt assumption that leads to such a conclusion. There is also a similar decomposition of terms for baryon formation in this scheme which involves many more terms. The reader is referred to Ref. [1] for further details.

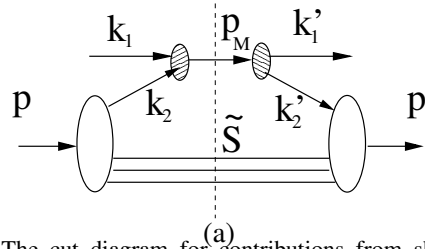


FIG. 1: The cut diagram for contributions from shower-thermal quark recombination to the single meson fragmentation function.

[1] A. Majumder, E. Wang, and X.-N. Wang (2005), nucl-th/0506040.